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Source: *The Journal of Finance*, Vol. 50, No. 5 (Dec., 1995), pp. 1635-1653
Published by: Blackwell Publishing for the American Finance Association
Stable URL: http://www.jstor.org/stable/2329329
Accessed: 25/11/2009 10:31

THE JOURNAL OF FINANCE • VOL. L, NO. 5 • DECEMBER 1995

# The Allocation of Informed Trading Across Related Markets: An Analysis of the Impact of Changes in Equity-Option Margin Requirements

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**ABSTRACT**

We examine the impact of changes in equity-option margin requirements on the liquidity of options and underlying stock markets. We find that the decrease in margin was associated with an increase in spreads and trade informativeness, and a decrease in depth for the underlying stocks. In contrast, option spreads decreased indicating a change in the relative allocation of informed traders between the two markets. When the required margin was increased, no significant change was observed in the underlying stocks, but option spreads increased. Overall, our results indicate that uninformed traders are more sensitive to the margin dimension of trading costs.

FEDERAL REGULATION OF SECURITIES margins was mandated by Congress in October 1934 to promote market integrity and curb excessive volatility. Several studies examine whether margin requirements have achieved these objectives. Specifically, these studies investigate the relation of margin with price, trading volume, and volatility in both stock and futures markets. Overall, the results of these studies indicate that changes in margin requirements have little influence on prices or volatility, and are inversely related to trading activity.[1]

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[1] A partial list includes Breeden (1985), Ferris and Chance (1988), Hardouvelis (1988, 1990), Hartzmark (1986), Hsieh and Miller (1990), Moser (1990, 1991, 1993), Pruitt and Tse (1993), Salinger (1989), Schwert (1989), Seguin (1990), and Seguin and Jarrell (1993). For a detailed review of the literature see Chance (1990). As argued by Chance (1990), the few studies that have found a relationship between margin requirements and volatility have been criticized for statistical problems that bias their results. An exception to this is the study by Seguin, who finds that OTC stocks that are added to the list of marginable securities experience a decrease in volatility, and whose methodology is not subject to the criticism in Chance.

In spite of the extensive research on the impact of margin regulations, a question that has largely been ignored is: *how do changes in margin requirements affect related markets?*[2] This question is especially important since the effects of changing margin regulations in one market may be transmitted to related markets through the arbitrage links that exist between these markets. In addition, changing margins in only one market would alter the relative trading costs across related markets. This would cause some investors to migrate from one market to another. Consequently, changes in the margin requirement in one market may influence the price formation process in a related market.

A change in margin in one market may also alter the relative composition of different investor groups in related markets if a certain class of investors is more sensitive to margins in making their trading venue decisions. For example, if uninformed traders are, on average, more capital constrained than informed traders, they would be more likely to migrate in response to changes in required margin. Thus, an increase in margin would increase the relative concentration of informed traders in the market with the margin change, and reduce the relative concentration of informed traders in other related markets.

In this article, we examine the effect of changes in equity-option margin requirements on the microstructure of both the options and underlying stock markets. This study contributes to the existing literature in four ways. First, it examines the relationship between option margin requirements and option liquidity, an issue that has not previously been analyzed. Second, by documenting the impact of option margins on the underlying stock market, it demonstrates that regulations aimed at a specific market can affect other markets linked, through arbitrage, to the targeted market. Third, this analysis sheds light on the relative allocation of informed trading in the options and underlying stock markets. Finally, it provides some insights into the relative sensitivity of informed versus uninformed traders to changes in trading costs.[3]

We find that when the margin required for writing equity options was reduced on January 31, 1986, bid-ask spreads declined in the options market and increased in the underlying stock market. After a small increase in the margin requirement on June 6, 1988, bid-ask spreads became wider in the options market, and there was no detectable change in stock market spreads.

We interpret this evidence as supporting the hypothesis that after the option market margin decreased, a higher proportion of uninformed traders migrated

[2] An exception is Moser (1990, 1991, 1993) who examines the impact of margin requirements in futures contracts on futures and cash price volatility.

[3] Schwert and Seguin (1993) and Umlauf (1993) argue that changing relative trading costs by imposing transaction taxes can force trading activity to migrate to markets with lower taxes. Also the possible interrelationship between margins and trading activity in related markets is the rationale used for the need for consistent margin requirements in all equity-related financial instruments. For a discussion on the issues surrounding the consistency of margin requirements see Estrella (1988) and Moser (1991, 1993).

from the stock market to the options market as compared to informed traders. This increased the relative concentration of informed traders in the underlying stock market, and decreased it in the options market. Similarly, in response to the increase in option margin requirements, a larger proportion of uninformed traders exited the options market, increasing the relative concentration of informed trading there. However, our result that there was no accompanying change in spreads in the underlying stocks suggests no significant change in the relative composition of traders in the stock market, perhaps because the size of the margin change was small.

Lee, Mucklow, and Ready (1993) point out that in addition to the bid-ask spread, market depth is also part of the stock market quote, and show that specialists actively manage adverse selection risk by adjusting both spread and depth. Specifically, they show that specialists increase spreads and decrease quoted depth in response to increases in perceived information asymmetry. Consistent with our evidence on bid-ask spreads, we find that the margin decrease was accompanied by a decrease in depth, while the depth did not change after the margin increase.

Finally, we provide some additional evidence that uninformed traders are more sensitive to margin requirements by estimating the impact of the margin change on the information content of trades in the underlying stock. Information content is measured using the vector autoregression approach developed by Hasbrouck (1991). Again, consistent with the evidence on spreads and depth, we find that trades in underlying stocks conveyed more information after the margin decrease, while informativeness of trades did not change after the margin increase.

It is possible that these results are driven by other, economy-wide factors that influenced markets during the period under investigation. Although it is difficult to rule out this possibility, we find that the stock market results do not hold for a control sample of nonoptioned stocks.

The remainder of the article is organized as follows. In Section I we develop the empirical predictions based on various models suggested in the literature. Section II describes our data sources and the construction of our sample. Section III documents the impact of margin changes on the microstructure of the options and stock markets, and Section IV concludes the article.

## I. The Predictions

Changes in margin requirements in the options markets affect the relative cost of trading in the options and stock markets. This, in turn, affects the frequency and intensity with which market participants trade. The impact of margin changes depends on whether the changes disproportionately affect informed or uninformed traders. John, Koticha, and Subrahmanyam (1993) argue that when the margin requirement in the options market increases, informed trading shifts to the stock market. The stock market specialist responds to this

by increasing the adverse selection component of the spread.[4] Since the option market makers face fewer information motivated traders, they reduce their spread. For the same reasons, a margin decrease in the options market increases the spread in the option market and reduces it in the underlying stock market. This argument would also imply that margin decreases in the options market would be associated with an increase in depth of the stock market, since Lee, Mucklow, and Ready (1993) show that specialists actively manage adverse selection risk by adjusting both spread and depth.[5]

Hartzmark (1986) demonstrates, in the context of futures markets, that a margin change would have a larger impact on uninformed traders if they have a larger probability of being caught short of liquid assets as compared to informed traders. If individual uninformed traders are more likely to be capital (credit) constrained as compared to informed institutional traders, then we would expect margin changes to have a greater impact on uninformed traders. In this scenario, the impact on spreads in the two markets, and depth in the stock market, will be opposite to that predicted by John, Koticha, and Subrahmanyam (1993).

The above arguments assume that there is a "fair" mix of informed and uninformed traders in the options market. However, if one class of investors dominates a market, changes in margins would have a larger proportional impact on that group of traders. Amin and Lee (1994) and Easley, O'Hara, and Srinivas (1994) provide evidence that options markets are primarily venues for information-based trading. In this case, margin changes in the options market would have a larger impact on informed traders. On the other hand, Brennan and Cao (1994) show in the context of a noisy rational expectations model that options markets are dominated by uninformed traders. Their results are consistent with Vijh (1990), who finds that the extent of information-related trading on the Chicago Board Options Exchange (CBOE) is very small. This would imply that option margin changes would affect uninformed traders more than informed traders.

Finally, it could be argued that margin changes in the options market will only impact the composition of traders in the options market without any corresponding change in the underlying stock market. Specifically, a margin decrease in the options market may cause *new* traders to enter this market since they now face lower transactions costs. This influx of traders would, then, have an impact on spreads in the options market with no corresponding changes in spread or depth in the stock market.

[4] The adverse selection component of the spread arises in a market that consists of informed and liquidity (uninformed) traders. In this framework, the market maker expects to lose on trades with the informed traders, and sets the bid-ask spread to maximize the difference between the expected gain from transactions with liquidity traders, and the expected loss from transactions with informed traders. See Bagehot (1971), Copeland and Galai (1983), and Glosten and Milgrom (1985) for more details.

[5] We do not discuss the impact on the depth in the options market since it is not quoted in this market.

This discussion suggests that the impact of a margin change on spreads and depth in the options and underlying stock markets is an empirical question. Specifically, if the options market is dominated by informed traders and/or this group of investors is more sensitive to the margin dimension of trading costs, we would expect spreads to decrease in the underlying stock market and increase in the options market in response to a margin decrease. The predicted impact on depth would be the opposite of that for spreads. In contrast, a margin decrease would be accompanied by an increase in underlying stock spreads, a decrease in quoted depth for stocks, and a decrease in option spreads if the options market was dominated by uninformed investors and/or they were more sensitive to margin changes.

## II. The Data

### *A. Margin Changes in Equity Options*

The margin required for writing options on individual stocks has been changed twice.[6] Before January 31, 1986, the initial margin required was 30 percent of the stock price plus (minus) the in-the-money (out-of-the-money) amount. On January 31, 1986, the margin was changed to the option premium plus the maximum of 15 percent of the underlying stock price minus the out-of-the-money amount (if any) or five percent of the stock price. The rationale behind this change was that the prechange margin requirement did not account for the risk of the position (as measured by the volatility of the underlying stock), while the new requirement did, since option premiums are increasing functions of volatility. For the options in our sample, this change caused required initial margin to drop by an average value of 38.03 percent, with a median drop of 38.50 percent and a range of 18.75 to 63.97 percent.

The second change in margin occurred on June 6, 1988 in response to the fear of "excessive" price movements following the crash of 1987. After June 6, 1988, margin was increased by five percent of the underlying stock price, and was calculated as the option premium plus the maximum of 20 percent of the underlying stock price minus the out-of-the-money amount (if any) or ten percent of the stock price.

### *B. The Analysis Period*

The period and options that we select for analysis ensure that option expiration characteristics are similar in the pre- and postmargin periods. First, to avoid problems associated with nontrading, the analysis is performed on the closest-maturity options.[7] Second, when the shortest maturity option has five days or less to maturity, we select the option with the next closest maturity to eliminate any effects of option expiration. Third, we exclude from our sample

[6] See Sofianos (1988) for more details on margin requirements for equity options.

[7] This choice is based on the results in Vijh (1990), who finds that these options are the most liquid.

period all observations on options that expire in the month prior to, the month of, and the month after the margin change. This exclusion is to avoid any distortion in our analysis caused by traders adjusting their position in anticipation of the margin change, or by trading of options in the postchange period written in the prechange period. Based on these criteria the options included in our margin decrease sample expire in October, November, and December 1985 in the premargin-change period, and April, May, and June 1986 in the postmargin-change-period. This corresponds to a premargin-change sample period of September 13, 1985 to December 13, 1985, and a postmargin-change sample period of March 24, 1986 to June 13, 1986. For the margin increase sample, the corresponding expiration months are February, March, and April 1988 for the premargin-change period of January 18, 1988 to April 8, 1988, and August, September, and October 1988 for the postmargin-change period of July 18, 1988 to October 14, 1988.

### C. The Sample

We first identify all firms that had stock transaction data available on the Institute for the Study of Securities Markets (ISSM) Data Base and option transaction data available on the Berkeley Options Data Base from September 13, 1985 to June 13, 1986 for the margin decrease sample, and from January 18, 1988 to October 14, 1988 for the margin increase sample. We exclude all stocks that split during this period or that split before this period and still had presplit options contracts trading during the period. This avoids distortions in our analysis arising from dual trading in both presplit and when-issued shares. These selection criteria result in a sample of 119 stocks and options at the time of the margin decrease, and 113 stocks and options at the time of the margin increase.

### D. The Control Sample

To ensure that our results are not driven by economy-wide factors, we also examine the behavior of a set of nonoptioned stocks listed on the ISSM Data Base. The control group for the margin decrease analysis consist of 130 firms that satisfied the requirements that a) they had no listed options at the time of the margin change, b) the stocks did not split or have both when-issued and presplit shares trading simultaneously in our period of analysis, and c) belonged to the largest 200 of the group of nonoptioned stocks both in terms of market equity capitalization and trading volume in the 60-day period preceding our sample period. The corresponding control sample for the margin increase analysis consists of 127 stocks that satisfied the same three criteria. It must be noted that the control sample consists of common stocks that are significantly smaller and less liquid than the sample of stocks with listed options.

*E. The Definitions of Variables Used in the Analysis*

The variables of interest in this article are the spread and depth in the underlying stock market and the spread in the options market. To estimate the daily spread, we follow a procedure similar to that in McInish and Wood (1992). First, for each quotation in a day, we calculate the relative spread as the ratio of the quoted bid-ask spread to the quote midpoint. Second, we calculate the weighted average of all relative spreads quoted in the day under consideration, where the weight for each quotation is the number of seconds the quotation is outstanding divided by the total number of seconds all quotations were outstanding in the day.[8] Then for each stock in our sample, we estimate the median of the daily weighted-average spreads in the premargin and postmargin change periods. Depth for each firm in the premargin and the postmargin change periods is obtained using a similar technique.

One empirical problem that needs to be considered when estimating daily weighted average spreads in the options market is that several option series trade on the same underlying stock. To include all traded options on a particular underlying stock in our analysis, we employ the following two step procedure to estimate the quoted spread for the options. First, we estimate the daily weighted average spread for all traded options on an underlying stock. Second, we weight each of these spreads by trading activity in that series, with trading activity being measured by daily contract volume. Thus, we calculate one composite value of the daily spread for options on a particular underlying stock, with the more heavily traded options having a greater weight in the spread measure. Then, as before, we estimate the time-series median of the spread for each option across days in the pre- and postchange period.

The other variables we control for in our analysis are price, volume, and volatility. Daily price is measured using the same technique as that outlined for spreads. Daily volume for each stock or option is the median value of total daily transaction volume in each period under consideration. Finally, volatility is measured as the variance of close-to-close returns in each period.

## III. Results

*A. The Impact of Option-Market Margin Changes on Quoted Spreads and Depth in the Underlying Stock Market*

We analyze the impact of margin changes on bid-ask spreads by estimating a cross-sectional regression using the difference in the natural logarithms of the postmargin-change and the premargin-change median relative spreads, $\Delta \ln(\text{Spread}_j)$, as the dependent variable and factors known to affect spread as independent variables. Specifically, the estimated model is the form:

$$\Delta \ln(\text{Spread}_j) = \alpha_0 + \alpha_1 \Delta \ln(\text{Price}_j) + \alpha_2 \Delta \ln(\text{Volume}_j) + \alpha_3 \Delta \ln(\text{Volatility}_j) + \alpha_4(\text{Margin change proxy}_j) + \varepsilon_j \quad (1)$$

[8] We discard all quotations before the open and after the close of the market.

In the above specification, $\Delta \ln(\text{Price}_j)$, $\Delta \ln(\text{Volume}_j)$ and $\Delta \ln(\text{Volatility}_j)$ are the differences in the natural logarithms of the postmargin-change and the premargin-change median prices, trading volumes, and daily return variances, respectively, for stock $j$. We use two proxies for the effect of change in margin. The first proxy is an option listing dummy, $Dopt_j$, that is assigned a value of one if stock $j$ has listed options and zero if the stock is nonoptioned (the control sample). Since the nonoptioned stocks are not directly affected by changes in option margin, the coefficient of this variable, $\alpha_4$, would indicate how spreads are affected by the margin change. The second proxy is the size of the change in required initial margin, $\Delta \ln(\text{Margin}_j)$.[9] This variable is defined as the difference in the natural logarithms of the postchange and the prechange margin requirements if stock $j$ has listed options and zero if the stock is nonoptioned. We include this variable in the analysis since we would expect the impact of the margin change to depend on the size of the change.

As stated earlier, Lee, Mucklow, and Ready (1993) show that spread and depth are determined jointly, with increases in depth, *ceteris paribus*, indicating an improvement in liquidity. This suggests that an analysis of the impact of margin changes on quoted depth would also have to control for variables known to affect bid-ask spreads. Therefore, we examine the impact of margin changes on quoted depth by estimating the following regression equation:

$$\Delta \ln(\text{Depth}_j) = \beta_0 + \beta_1 \Delta \ln(\text{Price}_j) + \beta_2 \Delta \ln(\text{Volume}_j) + \beta_3 \Delta \ln(\text{Volatility}_j) + \beta_4(\text{Margin change proxy}_j) + \varepsilon_j \qquad (2)$$

where $\Delta \ln(\text{Depth}_j)$ is the difference in the natural logarithms of the postmargin-change and the premargin-change median depths and all other variables are the same as equation (1). Again, our interest is the in the sign and significance of $\beta_4$.

The estimates of the parameters in equations (1) and (2) are presented in Table I along with $t$-statistics calculated using White's (1980) heteroskedasticity-consistent standard errors. In the spread equation, the coefficient estimate ($t$-statistic) of the listed options dummy is 0.0245 (2.12) for the margin decrease sample, and −0.0025 (−0.24) for the margin increase sample. This suggests that the margin decrease is associated with an increase in bid-ask spreads for optioned stocks, while spreads do not change after the margin increase. In addition, our results indicate that the increase in bid-ask spreads is significantly greater for those underlying stocks whose options experience a larger change in margin. This follows from the fact that the coefficient estimate ($t$-statistic) of the margin change variable is −0.0585 (−2.49). The estimate also suggests that the margin decrease causes underlying stock bid-ask

[9] The estimated equation for the margin increase sample excludes the second proxy since the increase is a uniform five percent.

**Table I**

## Impact of Margin Changes in the Options Market on the Quotes for Underlying Stocks

The estimates of the coefficients of cross-sectional regressions of the form:

$$\Delta \ln(\text{Spread}) = \alpha_0 + \alpha_1 \Delta \ln(\text{Price}) + \alpha_2 \Delta \ln(\text{Volume}) + \alpha_3 \Delta \ln(\text{Volatility}) + \alpha_4(\text{Margin change proxy}) + \varepsilon$$

$$\Delta \ln(\text{Depth}) = \beta_0 + \beta_1 \Delta \ln(\text{Price}) + \beta_2 \Delta \ln(\text{Volume}) + \beta_3 \Delta \ln(\text{Volatility}) + \beta_4(\text{Margin change proxy}) + \varepsilon$$

where $\Delta \ln(Spread)$ is the difference in the natural logarithm of the postmargin change and the premargin change relative bid-ask spread for the underlying stock, $\Delta \ln(Depth)$, $\Delta \ln(Price)$, $\Delta \ln(Volume)$ and $\Delta \ln(Volatility)$ are the corresponding differences in quoted depth, price per share, daily transaction volume, and variance of returns, respectively, and the effect of the margin change is proxied by (i) *Dopt*, a dummy variable that takes on a value of 1 for stocks with listed options and 0 for the control group of stocks with no listed options in equation (1), and (ii) $\Delta \ln(Margin)$, defined as the difference in the natural logarithm of required margin for stocks with listed options and 0 for the control group of stocks with no listed options in equation (2). The sample of 113 (119) stocks had an option trading on January 31, 1986 (June 6, 1988), the date of the margin decrease (increase), and also met the following criteria over the period September 13, 1985 to June 13, 1986 (January 18, 1988 to October 14, 1988): a) stock transactions data were available on the Institute for the Study of Securities Market (ISSM) Data Base, b) option transactions data were available on the Berkeley Options Data Base, and c) there was no stock split. The control sample for the margin decrease (increase) analysis consists of 130 (127) stocks that were in the largest 200 in terms of both market capitalization and trading volume among all stocks without listed options. The premargin change period is September 13, 1985 to December 13, 1985 (January 18, 1988 to April 8, 1988) for the margin decrease (increase) sample. The postmargin change period is March 24, 1986 to June 13, 1986 (July 18, 1988 to October 14, 1988) for the margin decrease (increase) sample. The figures in parentheses are *t*-statistics estimated using White's heteroskedasticity-consistent standard errors.

| | Margin Decrease Sample | | | | Margin Increase Sample | |
|---|---|---|---|---|---|---|
| | Dependent Variable | | | | | |
| Independent Variable | Bid-Ask Spread | | Depth | | Bid-Ask spread | Depth |
| | (1) | (2) | (1) | (2) | | |
| Intercept | 0.0230 | 0.0203 | −0.0077 | 0.0024 | −0.0782 | 0.2502 |
| | (2.06)** | (1.80)* | (−0.19) | (0.06) | (−5.94)*** | (5.80)*** |
| Price | −0.6495 | −0.6448 | −0.8330 | −0.8489 | −0.7545 | −0.9186 |
| | (−19.32)*** | (−19.11)*** | (−7.52)*** | (−7.80)*** | (−21.99)*** | (−5.24)*** |
| Transaction | −0.0760 | −0.0748 | 0.2471 | 0.2428 | −0.0573 | 0.4602 |
| volume | (−2.88)*** | (−2.83)** | (2.49)** | (2.43)** | (−1.92)* | (4.14)*** |
| Volatility | 0.0273 | 0.0274 | 0.0211 | 0.0216 | 0.0754 | −0.1749 |
| | (0.46) | (0.46) | (0.08) | (0.08) | (3.50)*** | (−3.06)*** |
| Margin | 0.0245 | −0.0585 | −0.0708 | 0.1755 | −0.0025 | 0.0250 |
| Change Proxy | (2.12)** | (−2.49)** | (−1.87)* | (2.36)** | (−0.24) | (0.70) |
| Adjusted $R^2$ | 0.68 | 0.68 | 0.22 | 0.22 | 0.71 | 0.40 |

Depth is the average of the number of shares a dealer is willing to buy at the bid and sell at the ask.

*** Indicates significance at the 1 percent level.

** Indicates significance at the 5 percent level.

* Indicates significance at the 10 percent level.

spreads to increase by an average value of 2.24 percent with the minimum (maximum) change in spread being 1.11 (3.77) percent.[10]

In the depth equation, the estimate ($t$-statistic) of the coefficient of the listed options dummy is $-0.0708$ ($-1.87$) for the margin decrease sample and 0.0250 (0.70) for the margin increase sample. These results reinforce our findings on the bid-ask spread. Specifically, after the margin decrease, the specialists revise their quotes by both increasing the spread and decreasing the quoted depth. In addition, we find that the change in depth is more pronounced the larger the margin change, since the coefficient of the margin change variable is 0.1755 with an associated $t$-statistic of 2.36. This estimate suggests that the margin decrease causes the quoted depth on the underlying stock to decrease by an average value of 6.67 percent with the change in depth ranging from $-3.29$ percent to $-11.23$ percent.[11] In contrast, the margin increase does not affect quoted depth.

One possible reason for this observed asymmetry in the impact of margin changes is that the margin decrease is much larger in magnitude than the margin increase. Specifically, one could argue that in the case of the margin decrease, the observed results on spread and depth can be attributed to a migration of more uninformed traders from the stock market to the options market as compared to informed traders. This follows from the fact that the margin change is large in magnitude, and, therefore, results in a substantial change in relative trading costs. On the other hand, the change in margin accompanying the margin increase is small, thus causing an insignificant change in relative trading costs across the two markets. In this framework, there would be an negligible impact on spreads and depth in the stock market since the margin change would not cause a significant amount of migration from the options to the stock market. This argument is supported by our empirical results. Specifically, we find that a one percent decrease in margin is associated with a 0.0585 percent increase in bid-ask spreads (see Table I, column 3). Thus, a five percent increase in margin would be associated with a 0.2925 percent decrease in spreads, a number that corresponds to the estimated coefficient of the listed options dummy in the bid-ask spread equation for the margin increase sample (see Table I, column 6). This result, therefore, supports the argument that the asymmetric response to the margin increase is a consequence of the fact that the change in margin is small.

One possible criticism of the above analysis is that it does not allow for time-series variation in the relationship between bid-ask spreads (or quoted depth) and the independent variables. To allow for changes in the relationship,

[10] This average change in bid-ask spreads of 2.24 percent is comparable in magnitude to the average change of 2.45 percent obtained from the estimation of equation (1) with the margin change being proxied by a listed options dummy variable.

[11] This average change in quoted depth of 6.67 percent is comparable in magnitude to the average change of 7.08 percent obtained from the estimation of equation (2) with the margin change being proxied by a listed options dummy variable.

we estimate the following cross-sectional regressions for each day in the 100-day period surrounding the margin change:[12]

$$\ln(\text{Spread}_{jt}) = \delta_{0t} + \delta_{1t} \ln(\text{Price}_{jt}) + \delta_{2t} \ln(\text{Volume}_{jt}) + \delta_{3t} \ln(\text{Volatility}_{jt}) + \delta_{4t}\text{Dopt}_j + \varepsilon_{jt} \quad (3)$$

$$\ln(\text{Depth}_{jt}) = \theta_{0t} + \theta_{1t} \ln(\text{Price}_{jt}) + \theta_{2t} \ln(\text{Volume}_{jt}) + \theta_{3t} \ln(\text{Volatility}_{jt}) + \theta_{4t}\text{Dopt}_j + \varepsilon_{jt} \quad (4)$$

In the above models, $\text{Spread}_{jt}$ is the weighted average relative bid-ask spread, $\text{Depth}_{jt}$ is the quoted depth, $\text{Price}_{jt}$ is the price per share, $\text{Volume}_{jt}$ is the transaction volume, $\text{Volatility}_{jt}$ is the squared return for stock $j$ on day $t$, and $\text{Dopt}_j$ is an option listing dummy that is assigned a value of one if stock $j$ has listed options and zero if the stock is nonoptioned (the control sample). Given previous results in the literature on the impact of options listings on bid-ask spreads and quoted depth for the underlying stocks, we would expect optioned stocks to have lower spread and higher depth, i.e., $\delta_{4t} < 0$ and $\theta_{4t} > 0$.[13] If the margin change has an impact on spread and depth, we would expect $\delta_{4t}$ and $\theta_{4t}$ to change in opposite directions around the date of the margin change. Specifically, given the results from the estimation of equations (1) and (2), we would expect $\delta_{4t}$ to increase and $\theta_{4t}$ to decrease around the margin decrease, while the opposite holds for a margin increase.

Figures 1 and 2 provide time-series plots of the two coefficients for the 100-day period surrounding the margin changes. The signs of these coefficients are as predicted. In addition, the time-series behavior of these coefficients is consistent with the results reported previously. Specifically, $\delta_{4t}$ increases from a median value of $-0.118$ before to a median value of $-0.092$ after the margin decrease, while $\theta_{4t}$ decreases from 0.114 to 0.076. The corresponding figures around the margin increase are $-0.029$ and $-0.058$, respectively for $\delta_{4t}$, and 0.078 and 0.172, respectively for $\theta_{4t}$. These results provide further evidence that the bid-ask spread for optioned stocks increases relative to nonoptioned stocks after the margin decrease. In contrast, the quoted depth decreases for optioned stocks relative to nonoptioned stocks. Also, the effects of the margin increase on the spread and depth are the opposite of that for the margin decrease.

### *B. The Impact of Option-Market Margin Changes on Quoted Spreads in the Options Market*

The previous subsection provides some evidence that the quoted spread and depth in the stock market are unchanged after a margin increase in the options market. In addition, we find that spreads increase and depth decreases after

[12] A similar method is used by Hanley, Kumar, and Seguin (1993) to analyze the impact of price stabilization around new issues on bid-ask spreads.

[13] For example, see Kumar, Sarin, and Shastri (1994).

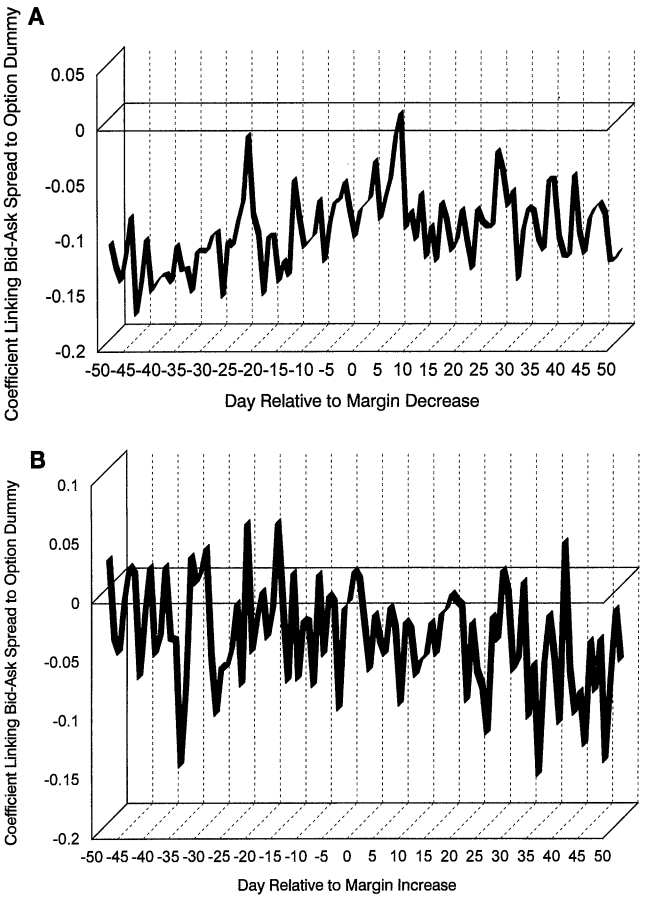


**Figure 1. Impact of margin changes in the options market on the bid-ask spreads for underlying stocks.** These figures plot estimates of the coefficient linking bid-ask spreads to an option dummy variable ($\delta_{4t}$) for a 101-day period around the margin change. The coefficient is estimated from cross-sectional regressions of the form $\ln \text{Spread}_{jt} = \delta_{0t} + \delta_{1t} \ln \text{Price}_{jt} + \delta_{2t} \ln \text{Volume}_{jt} + \delta_{3t} \ln \text{Volatility}_{jt} + \delta_{4t}\text{Dopt}_j + \varepsilon_{jt}$ where *Spread* is the relative bid-ask spread for stock $j$ on day $t$, *Price* is the price per share, *Volume* is the transaction volume, *Volatility* is the squared return, and *Dopt* is a dummy variable that takes on a value of 1 for stocks with listed options and 0 for the control group of stocks with no listed options. The sample of 113 (119) stocks had an option trading on January 31, 1986 (June 6, 1988), the date of the margin decrease (increase), and also met the following criteria over the period September 13, 1985 to June 13, 1986 (January 18, 1988 to October 14, 1988): a) stock transactions data were available on the Institute for the Study of Securities Market (ISSM) Data Base, b) option transactions data were available on the Berkeley Options Data Base, and c) there was no stock split. The control sample for the margin decrease (increase) analysis consists of 130 (127) stocks that were in the largest 200 in terms of both market capitalization and trading volume among all stocks without listed options.

the margin decrease. The results on the impact of margin decreases are consistent with the argument that uninformed traders are more sensitive to margin changes. Specifically, they suggest that after the margin decrease, more uninformed traders migrate from the stock market to the options market,

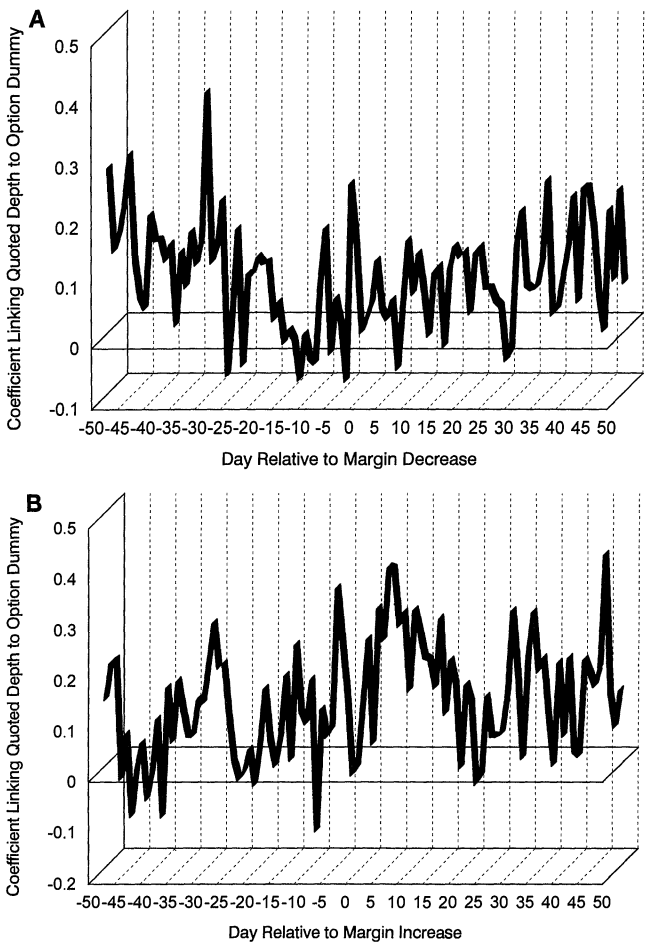


**Figure 2. Impact of margin changes in the options market on the quoted depth for underlying stocks.** These figures plot estimates of the coefficient linking quoted depth to an option dummy variable ($\Theta_{4t}$) for a 101-day period around the margin change. The coefficient is estimated from cross-sectional regressions of the form $\ln \text{Depth}_{jt} = \Theta_{0t} + \Theta_{1t} \ln \text{Price}_{jt} + \Theta_{2t} \ln \text{Volume}_{jt} + \Theta_{3t} \ln \text{Volatility}_{jt} + \Theta_{4t}\text{Dopt}_j + \varepsilon_{jt}$ where *Depth* is quoted depth for stock $j$ on day $t$, *Price* is the price per share, *Volume* is the transaction volume, *Volatility* is the squared return, and *Dopt* is a dummy variable that takes on a value of 1 for stocks with listed options and 0 for the control group of stocks with no listed options. The sample of 113 (119) stocks had an option trading on January 31, 1986 (June 6, 1988), the date of the margin decrease (increase), and also met the following criteria over the period September 13, 1985 to June 13, 1986 (January 18, 1988 to October 14, 1988): a) stock transactions data were available on the Institute for the Study of Securities Market (ISSM) Data Base, b) option transactions data were available on the Berkeley Options Data Base, and c) there was no stock split. The control sample for the margin decrease (increase) analysis consists of 130 (127) stocks that were in the largest 200 in terms of both market capitalization and trading volume among all stocks without listed options.

increasing the probability of the stock specialist facing an information-motivated trade. This argument would also imply that after the margin decrease, the market makers in the options market will be faced with a smaller fraction

of informed traders and will, therefore, revise their quoted spreads downwards. Similarly, after the margin increase, we expect quoted spreads in the options market to increase. This holds irrespectively of whether the margin increase causes more uninformed traders to migrate to the stock market or drop out altogether.

To examine this issue further, we investigate the impact of margin changes on spreads in the options market by estimating the following equation:

$$\Delta \ln(\text{Spread}_j) = \gamma_0 + \gamma_1 \Delta \ln(\text{Price}_j) + \gamma_2 \Delta \ln(\text{Volume}_j) + \gamma_3 \Delta \ln(\text{Volatility}_j) + \varepsilon_j \quad (5)$$

where all variables are as previously defined. The variable of interest in equation (5) is the intercept. The hypothesis that uninformed traders are more sensitive to margin changes would receive support if the intercept is negative for the margin decrease sample, and positive of the margin increase sample. In addition, since we would expect the impact of the margin change to depend on the size of the change, we also estimate equation (5) for the margin decrease sample with an additional independent variable, $\Delta \ln(Margin_j)$. Again, our hypothesis would receive support if the coefficient of this variable is positive.

The parameter estimates of these regressions are presented in Table II. The estimates of the intercept (Table II, columns 2 and 4) and the coefficient of the margin change variable (Table II, column 3) have the predicted signs. Specifically, there is a decrease in the spread after a margin decrease (intercept is $-0.1210$ with an associated t-statistic of $-2.37$), while the opposite holds true after the margin increase (intercept is 0.0456 with an associated $t$-statistic of 2.18). In addition, our results indicate spreads decrease more for options which have the larger reduction in margin since the coefficient of the size of the margin change is 0.9599 ($t$-statistic of 2.93). Finally, the intercept in this equation is positive and significant, indicating that on average spreads increase for options and decrease only of those options with a large margin decrease.

### *C. The Impact of Option-Market Margin Changes on Informativeness of Trades in the Underlying Stock Market*

The results presented in the previous subsections are consistent with the hypothesis that the margin decrease induces a larger migration of uninformed traders as compared to informed investors from the underlying stock market to the options market while the margin increase causes more uninformed traders to exit the options market and drop out altogether. This suggests that trades in the stock market should become more informative after the margin decrease. On the other hand, informativeness should not change after the margin increase.

**Table II**

## Impact of Margin Changes in the Options Market on the Bid-Ask Spreads for Options

The estimates of the coefficients of cross-sectional regressions of the form:

$$\Delta \ln(\text{Spread}) = \gamma_0 + \gamma_1 \Delta \ln(\text{Price}) + \gamma_2 \Delta \ln(\text{Volume}) + \gamma_3 \Delta \ln(\text{Volatility}) + \gamma_4 \Delta \ln(\text{Margin}) + \varepsilon$$

where $\Delta \ln(Spread)$ is the difference in the natural logarithm of the postmargin change and the premargin change relative bid-ask spread for the option, $\Delta \ln(Price)$, $\Delta \ln(Volume)$ $\Delta \ln(Volatility)$ and $\Delta \ln(Margin)$ are the corresponding differences in option market price, daily transaction volume, variance of returns for the underlying stock, and required margin. The size of the margin change is not used in the margin increase regression since the size of the margin increase is uniform across all options. The sample of 113 (119) stocks had an option trading on January 31, 1986 (June 6, 1988), the date of the margin decrease (increase), and also met the following criteria over the period September 13, 1985 to June 13, 1986 (January 18, 1988 to October 14, 1988): a) stock transactions data were available on the Institute of the Study of Securities Market (ISSM) Data Base, b) option transactions data were available on the Berkeley Operations Data Base, and c) there was no stock split. The premargin change period is September 13, 1985 to December 13, 1985 (January 18, 1988 to April 8, 1988) for the margin decrease (increase) sample. The postmargin change period is March 24, 1986 to June 13, 1986 (July 18, 1988 to October 14, 1988) for the margin decrease (increase) sample. The figures in parentheses are *t*-statistics estimated using White's heteroskedasticity-consistent standard errors.

| | Margin Decrease Sample | | Margin Increase Sample |
|---|---|---|---|
| Independent variables | (1) | (2) | |
| Intercept | −0.1210 | 0.7166 | 0.0456 |
| | (−2.37)** | (2.67)** | (2.18)** |
| Price | −0.5012 | −0.4178 | −0.3365 |
| | (−9.25)*** | (−7.79)*** | (−7.39)*** |
| Transaction volume | 0.2080 | 0.1670 | −0.0815 |
| | (2.24)** | (2.01)* | (−3.73)*** |
| Stock volatility | −0.0374 | −0.0505 | −0.0041 |
| | (−0.36) | (−0.60) | (−0.08) |
| Size of margin change | | 0.9599 | |
| | | (2.93)*** | |
| Adjusted $R^2$ | 0.46 | 0.51 | 0.35 |

*** Indicates significance at the 1 percent level.
** Indicates significance at the 5 percent level.
* Indicates significance at the 10 percent level.

Several approaches have been used in the literature to estimate the degree of asymmetric information in spreads.[14] However, as suggested by Choi and Subrahmanyam (1994), the approaches of Stoll (1989) and George, Kaul, and Nimalendran (1991) suffer from the drawback that they do not explicitly consider the possibility that large trades could convey more information than

[14] See, for example, Glosten and Harris (1988), Stoll (1989) and George, Kaul, and Nimalendran (1991).

small trades. Specifically, these techniques use daily (rather than intraday) data, and consequently are not able to analyze the effect of transaction quantities on intraday transaction prices and quote revisions. We use an approach developed by Hasbrouck (1991) to measure the changes in the degree of asymmetric information after margin changes. The advantage of this approach is that it explicitly models the effects of trade size on price and quote revisions.

The Hasbrouck technique is based on a model that decomposes a security's quote midpoint into its random walk and its stationary components. Specifically, the quote midpoint, $q_t$, is defined as the sum of the true price, $m_t$, and a term that embodies microstructure imperfections, $s_t$. The efficient price is assumed to evolve as a random walk, i.e., $m_t + w_t$, where the innovations $w_t$ reflect updates to the public information set and have the properties $Ew_t = 0$, $Ew_t^2 = \sigma_w^2$, $Ew_t w_T = 0$ for $t \neq T$.

In this framework, a summary measure of information asymmetry is defined as:

$$R_w^2 = \text{Var}[E(w_t|x_t - E(x_t|\phi_{t-1}))]/\text{Var}[w_t] = \sigma_{w,x}^2/\sigma_w^2 \tag{6}$$

where $x_t$ is a vector of trade attributes, and $\phi_{t-1}$ is the public information set prior to the trade at $t$.

To measure $R_w^2$, Hasbrouck uses a vector autoregression (VAR) model for revisions in quotes, $r_t$ $(= q_t - q_{t-1})$, and trade attributes, $x_t$, defined as:

$$\begin{aligned} r_t &= a_1 r_{t-1} + a_2 r_{t-2} + \cdots + b_0 x_t + b_1 x_{t-1} + \cdots v_{1,t} \\ x_t &= c_1 r_{t-1} + c_2 r_{t-2} + \cdots + d_1 x_{t-1} + d_2 x_{t-2} + \cdots v_{2,t} \end{aligned} \tag{7}$$

where the error terms are mean zero and serially uncorrelated with $\text{Var}(v_{1,t}) = \sigma_1^2$, $\text{Var}(v_{2,t}) = \Omega$, and $E(v_{1,t}, v_{2,t}) = 0$. The Vector Moving Average (VMA) representation corresponding to the VAR model is:

$$\begin{aligned} r_t &= v_{1,t} + a_1^* v_{1,t-1} + \cdots + b_o^* v_{2,t} + b_1^* v_{2,t-1} + \cdots \\ x_t &= c_0^* v_{1,t} + c_1^* v_{1,t-1} + \cdots + v_{2,t} + d_1^* v_{2,t-1} + \cdots \end{aligned} \tag{8}$$

with

$$\sigma_{w,x}^2 = \sum_{j=0}^{\infty} b_j^* \Omega b_j^{*\prime} \qquad \text{and} \qquad \sigma_w^2 = \sigma_{w,x}^2 + \left(1 + \sum_{j=1}^{\infty} a_j^*\right)^2 \sigma_1^2.$$

In the implementation of this technique, we use one trade attribute defined as $+(\text{trade volume})^{1/2}$ or $-(\text{trade volume})^{1/2}$ if the trade is above or below the quote midpoint, respectively, and we employ five lags in the VAR model and 10

**Table III**

## Impact of Margin Changes in the Options Market on the Informativeness of Trades in the Underlying Stock

Changes in the summary informativeness of trades ($R_w^2$) in the underlying stocks around changes in the margin requirements in the options market. The summary informativeness of stock trades is estimated using the technique in Hasbrouck (1991). The sample of 113 (119) stocks had an option trading on January 31, 1986 (June 6, 1988), the date of the margin decrease (increase), and also met the following criteria over the period September 13, 1985 to June 13, 1986 (January 18, 1988 to October 14, 1988): a) stock transactions data were available on the Institute for the Study of Securities Market (ISSM) Data Base, b) option transactions data were available on the Berkeley Options Data Base, and c) there was no stock split. The control sample for the margin decrease (increase) analysis consists of 130 (127) firms that were in the largest 200 in terms of both market capitalization and trading volume among all firms without listed options. The premargin change period is September 13, 1985 to December 13, 1985 (January 18, 1988 to April 8, 1988) for the margin decrease (increase) sample. The postmargin change period is March 24, 1986 to June 13, 1986 (July 18, 1988 to October 14, 1988) for the margin decrease (increase) sample.

| | Margin Decrease Sample | | Margin Increase Sample | |
|---|---|---|---|---|
| | Optioned Stocks | Nonoptioned Stocks | Optioned Stocks | Nonoptioned Stocks |
| Median value before change in margin | 0.383 | 0.296 | 0.418 | 0.280 |
| Median value after change in margin | 0.402 | 0.291 | 0.419 | 0.286 |
| Wilcoxon signed rank $z$-statistic | 2.39** | −0.27 | −1.11 | −0.16 |
| Proportion of stocks with increases | 0.57 | 0.52 | 0.38 | 0.47 |

** Indicates significance at the 5 percent level.

lags in the VMA representation.[15] $R_w^2$ is computed for each firm in the pre- and postchange period. The null hypothesis would suggest that $R_w^2$ would increase after the margin decrease, and not change after the margin increase.

The results of this analysis are presented in Table III. As can be seen from the table, the value of $R_w^2$ increases as predicted after the margin decrease. In addition, we find no change in informativeness of stock trades after the margin increase. These results cannot be attributed to market-wide changes in informativeness since the control sample of nonoptioned stocks experiences no change in informativeness in both cases.

## IV. Summary and Conclusions

This article examines the impact of margin changes in the options market on the microstructure of the options and underlying stock markets. We find that the margin decrease of January 1986 is associated with increases in bid-ask spreads and the summary informativeness of stock trades, and decreases in quoted depth in the underlying stock market. The changes in spread and depth are more pronounced for stocks whose options have a larger change in margin.

[15] The sign assigned to the trade attribute variable follows the technique in Lee and Ready (1991). The choice of (trade volume)$^{1/2}$ as the trade attribute is based on the observation in Hasbrouck that price changes are nonlinear and concave in the trade attribute.

In addition, the margin increase of June 1988 is associated with no change in spreads, depth, or informativeness of trades in the underlying stocks. We also find that the margin decrease is associated with a decrease in spreads in the options markets, while the opposite holds after the margin increase. This decrease in spreads after the margin decrease is more pronounced for options that have a larger change in margin.

These results provide support for the hypothesis that uninformed traders are more sensitive to the margin dimension of trading costs. Specifically, they suggest that the margin decrease causes proportionally more uninformed than informed traders to migrate from the stock to the options market. This migration increases the concentration of informed traders in the stock market, resulting in an increase in quoted spreads and trade informativeness, and a decrease in quoted depth. The opposite holds true for the options market. On the other hand, the increase in margin causes a disproportionately larger number of uninformed traders to exit the options market and drop out altogether. This results in no change in spread, depth, and trade informativeness in the stock market, but increases spreads in the options market.

## REFERENCES

Amin, K. J., and C. Lee, 1994, Option trading and earnings news dissemination, Working paper, University of Michigan.

Bagehot, W., 1971, The only game in town, *Financial Analysts Journal* 22, 12–14.

Breeden, D. T., 1985, Futures margins as predictors of price volatility, Working paper, Duke University.

Brennan, M. J., and H. H. Cao, 1994, Information, trade and derivative securities, Working paper, UCLA.

Chance, D. M., 1990, The effects of margins on the volatility of stock and derivative markets: A review of the evidence, *New York University Monograph Series in Finance and Economics* 2.

Choi, H., and A. Subrahmanyam, 1994, Using intraday data to test the effects of index futures on the underlying stock markets, *Journal of Futures Markets* 14, 293–322.

Copeland, T. E., and D. Galai, 1983, Information effects on the bid-ask spread, *Journal of Finance* 25, 1457–1469.

Easley, D., M. O'Hara, and P. S. Srinivas, 1994, Option volume and stock prices: Evidence on where informed traders trade, Working paper, Cornell University.

Estrella, A., 1988, Consistent margin requirements: Are they feasible? *Federal Reserve Bank of New York Quarterly Review* 13, 61–79.

Ferris, S. P., and D. M. Chance, 1988, Margin requirements and stock market volatility, *Economics Letters* 28, 251–254.

George, T., G. Kaul, and M. Nimalendran, 1991, Estimation of the bid-ask spread and its components, *Review of Financial Studies* 4, 623–656.

Glosten, L., and L. Harris, 1988, Estimating the components of bid-ask spreads, *Journal of Financial Economics* 21, 123–142.

Glosten, L., and L. Milgrom, 1985, Bid, ask and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics* 14, 71–100.

Hanley, K., A. Kumar, and P. Seguin, 1993, Price stabilization in the market for new issues, *Journal of Financial Economics* 34, 177–198.

Hardouvelis, G. A., 1988, Margin requirements and stock market volatility, *Federal Reserve Bank of New York Quarterly Review* 13, 80–89.

Hardouvelis, G. A., 1990, Margin requirements, volatility, and the transitory component of stock prices, *American Economic Review* 80, 736–762.

Hartzmark, M. L., 1986, The effects of changing margin levels on futures market activity, the composition of traders in the market and price performance, *Journal of Business* 59, 147–180.

Hasbrouck, J., 1991, The summary informativeness of stock trades: An econometric analysis, *Review of Financial Studies* 4, 571–595.

Hsieh, D. A., and M. H. Miller, 1990, Margin requirements and stock market volatility, *Journal of Finance* 45, 3–29.

John, K., A. Koticha, and M. Subrahmanyam, 1993, The micro-structure of options markets: Informed trading, liquidity, volatility and efficiency, Working paper, New York University.

Kumar, R., A. Sarin, and K. Shastri, 1994, The impact of options trading on the level of information asymmetry in the market for the underlying security: An empirical analysis, Working paper, University of Pittsburgh.

Lee, C., B. Mucklow, and M. Ready, 1993, Spreads, depths and the impact of earnings information: An intraday analysis, *Review of Financial Studies* 6, 345–376.

Lee, C., and M. Ready, 1991, Inferring trade direction from intraday data, *Journal of Finance* 46, 733–746.

McInish, T., and R. Wood, 1992, An investigation of transactions data for the NYSE stocks, *Journal of Finance* 47, 753–764.

Moser, J. T., 1990, Evidence on the impact of futures margin specifications on the performance of futures and cash markets, *Geld, Banken, und Versicherungen*, 619–672.

Moser, J. T., 1991, The implications of futures margin changes for futures contracts: An investigation of their impact on price volatility, market participation and cash-futures covariance, *The Review of Futures Markets* 10, 376–397.

Moser, J. T., 1993, Changes in futures margin specifications and the performance of futures and cash markets, *Research in Financial Services: Private and Public Policy* 5, 95–129.

Pruitt, S. W., and K. S. M. Tse, 1993, The price, volatility, volume, and liquidity effects of changes in Federal Reserve margin requirements on both marginable and nonmarginable OTC stocks, Working paper, Indiana University.

Salinger, M. A., 1989, Stock market margin requirements and volatility: Implications for the regulation of stock index futures, *Journal of Financial Services Research* 3, 121–138.

Schwert, G. W., 1989, Margin requirements and stock volatility, *Journal of Financial Services Research* 3, 153–164.

Schwert, G. W., and P. J. Seguin, 1993, Securities transaction taxes: An overview of costs, benefits and unresolved questions, *Financial Analysts Journal* 49, 27–35.

Seguin, P. J., 1990, Stock volatility and margin trading, *Journal of Monetary Economics* 26, 101–121.

Seguin, P. J., and G. A. Jarrell, 1993, Margin eligibility, leverage, and the crash of '87, *Journal of Finance* 48, 1457–1473.

Sofianos, G., 1988, Margin requirements on equity instruments, *Federal Reserve Bank of New York Quarterly Review* 13, 47–60.

Stoll, H. R., 1989, The components of bid-ask spreads: Theory and empirical tests, *Journal of Finance* 44, 115–134.

Umlauf, S. R., 1993, Transaction taxes and stock market behavior: The Swedish experience, *Journal of Financial Economics* 33, 227–240.

United States Presidential Task Force on Market Mechanisms, 1988, *Report of the Presidential Task Force on Market Mechanisms: Submitted to the President of the United States, the Secretary of the Treasury, and the Chairman of the Federal Reserve Board* (U. S. Government Printing Office, Washington, D.C.).

Vijh, A. M., 1990, Liquidity of the CBOE equity options, *Journal of Finance* 45, 1157–1179.

White, H., 1980, A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity, *Econometrica* 48, 817–838.